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NOTES FOR STUDENTS.

BEFORE THE Botanical Society of America, at the Columbus meeting Professor D. T. MacDougal read a paper on *Symbiosis and saprophytism*, of which the following is a synopsis :

At the last meeting of the society I read a paper in description of my work upon a large number of herbaceous mycorrhizal plants,² and a short note was presented before the meeting of the Society for Plant Physiology and Morphology, in December 1898, in which a delimitation of the terms saprophyte and symbiosis was attempted. Attention was also called to the fact that only two seed plants, *Wulfschlegelia* and *Cephalanthera*, may be truly designated as saprophytes, all other species of so-called holosaprophytes being symbiotic with mycorrhizal fungi.

During the last year my efforts have been directed first to ascertain the adaptations undergone by these true saprophytes, and compare such changes with those undergone by mycorrhizal forms. Secondly, evidence which might have a bearing upon the physiological relations of a seed plant and its mycorrhizal fungus has been carefully sought for.

Cephalanthera, the saprophyte examined, showed alterations in structure generally similar to those of mycorrhizal forms ; but, in exception to the majority of chlorophyllless species, it retains the stomata of the leaves, and has developed no underground transpiratory organs.

The roots, unlike those of most mycorrhizal forms, are deeply buried in the soil, on account of which the number of good herbarium specimens to be found is extremely small. Two types of these organs are present : a fibrotype, with a reduction and fusion of the stelar components, and with radially elongated cortex. This variation has hitherto been regarded as a result of the presence of a fungus as in mycorrhiza, while as a matter of fact it is an adaptation to humus foods. The second type of root is devoted to storage and has a normal multiplication of the cortical elements. Both types agree closely with the two kinds of roots formed by *Wulfschlegelia*, which still further strengthens the conclusions given above.

The lack of apparatus for the conversion of radiant energy indicates that these two saprophytes must receive their entire supply from the chemical energy of the humus compounds taken up, and we may decide inferentially that substantial modifications of the minute mechanism of absorption must have taken place, entailing also unusual osmotic conditions. In general these two seed saprophytes live like fungi, although capable of forming starch.

The coralloid formations on the offsets of *Calypso*, which are found from Norway to Washington, have been examined, and the result of the development of these adventitious mycorrhizas is quite similar to that already described in *Apleticum*. The occurrence of the coralloid mycorrhiza is coupled

² Published in the *Annals of Botany* 13 : —. March 1899.

with a diminution of the leaves, the roots, and the storage organs, indicating an increased acquisition of highly organized food-material; a variation which will have the same ultimate influence on the species as in *Aplectrum*, and is doubtless responsible for many of the so-called aberrant forms of leaves and flowers reported.

This species and *Corallorhiza Arizonica* were examined with especial reference to the relations of the seed plant and the endotropic fungus. *Corallorhiza Arizonica* is entirely free from chlorophyll, and the aerial shoot has lost the stomata. The subterranean rhizome and its coralloid branches are each furnished with separate types of motile stomata, however, which function during the entire year, but clearly serve transpiratory and respiratory needs alone.

The arrangement of the fungus is one which has been found in nearly all of the endotropic mycorrhizas hitherto examined, and its study has yielded some important results.

The hyphæ of the fungus extend themselves in comparatively straight threads longitudinally toward the tip of the organ in the sub-epidermal region of the cortex, and this portion remains alive even in old members constituting what may be designated as the "vegetative mycelium." The entrance of the hyphæ of the vegetative mycelium into the young cortical cells causes almost no disturbance in the character of the latter, and no important interchange between the two plants ensues in this region.

As the growth of the root and the contained vegetative mycelium goes on, the younger portion of the mycelium sends out hyphal branches which extend out through the epidermis and may or may not traverse the hairs into the humus soil; these are very clearly absorbing organs. At the same time another set of branches penetrate to the median region of the cortex and both set up and undergo profound disturbances. The tips of the hyphæ are attracted to the vicinity of the nuclei. Dense coils and sometimes large vesicles are formed which serve as organs of interchange between the fungus and the seed plant. The starch contained in the cortical cells inhabited by these organs is used by the fungus; then, with the maturity of this general region, the organs of interchange and the large amount of contained proteid are set free and become available to the higher plant.

Here then is the character of the partnership of the two plants:

The seed plant furnishes a habitat for the vegetative mycelium of the fungus, and yields to it certain carbohydrate foods, principally starch. The fungus takes up the humus products from the soil by means of its external branches, conducts them to the inner branches in the cortex of the higher plant, and manufactures proteids, of which a portion is used in its own metabolism of course, but the greater part is yielded to the seed plant.

It follows as a necessary corollary from the above conclusions, that Frank's theory that mycorrhizal adaptations are fungus traps and that the seed plant

derives the entire advantage from the association is no longer tenable. Likewise the theory of Janse, that endotropic fungi which form mycorrhizas are negatively chemotropic to oxygen and bear the same relation to the seed plant as the organism in the leguminous tubercle, is not capable of universal application. Such relation has been proven by Nobbe and Hiltner between *Podocarpus* and the peronosporous fungus which forms endotropic mycorrhiza with it, but in no other instance.

At this stage of our investigations, then, two distinct physiological types of endotropic mycorrhizas are recognized: One adapted for nitrogen fixation, and a second for the absorption and modification, perhaps oxidation, of humus products by the fungus and their liberation in the tissues of the higher plant. The greater number of examples are included under the last type.

Ectotropic or sheathing mycorrhizas such as *Monotropa* perhaps approximate more nearly to the latter type.³

THE PAPER read before the Botanical Society of America, at Columbus, entitled "The effect of centrifugal force upon the cell," by Professor D. M. Mottier, discussed in detail the effect of centrifugal force varying from 1800 to 1900 times that of gravity, acting for definite short periods of time, upon cells of certain algæ, mosses, and phanerogams. In all cells operated with, the movable plasmic contents, together with the inclusions, were made to fall into a compact mass at the end of the cell. In cells which were not killed outright or too badly injured, so that death resulted soon afterwards, the displaced cell-contents gradually redistributed themselves in due course of time.

The most strikingly interesting phenomena are presented by dividing cells and in the behavior of the nucleolus. In dividing cells of such algæ as *Cladophora* and *Spirogyra*, the cell-wall in process of formation at the time of centrifugal action was never completed. The chloroplasts, nuclei, and other displaced contents, on becoming redistributed, pass back through the opening in the partly formed cell wall provided this opening were not too small.

Cells often divide normally before the contents become redistributed, especially in *Cladophora* and *Spirogyra*, thus giving rise to two daughter cells of unequal size, a smaller one appearing a deep green from the large amount of chlorophyll, and a larger one partly colorless with only a little chlorophyll. In certain cells of the perome of *Zea Mays* and other phanerogams, the nucleolus was thrown out through the nuclear membrane into the cytoplasm. These nucleoli never re-entered the nucleus.

Other important observations were presented touching upon the dividing cell and nucleus.⁴

³ The full paper will be published in the *Bulletin of the Torrey Botanical Club*.

⁴ This paper is published in the *Annals of Botany* for September 1899.